CHAPTER 6

DATA COLLECTION

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6.1 OVERVIEW

6.1.1 Introduction

It is necessary to identify the types of data that will be required prior to conducting the engineering analysis. The effort necessary for data collection and compilation should be tailored to the importance of the project. Not all data discussed in this Chapter will be needed for every project.

Data collection for a specific project must be commensurate with the project scope and tailored to:

- site conditions;
- scope of the engineering analysis;
- social, economic, environmental and archaeological requirements;
- unique project requirements; and
- regulatory requirements.

Uniform or standardized survey requirements for all projects may prove uneconomical or data deficient for a specific project. Special instructions outlining data requirements may have to be provided to the survey party by the designer for unique sites.

6.1.2 Data Requirements

This Chapter outlines the types of data that are normally required for drainage analysis and design, possible sources and other aspects of data collection. The following subjects are presented in this Chapter:

- sources and types of data,
- survey information,
- field reviews, and
- data evaluation.

6.2 SOURCES OF DATA

6.2.1 Objectives

These are:

- Identify possible sources of data.

- Rely on the Department's experience as to which sources will most likely yield desired data.

- Utilize the guides in this Chapter for data sources. Acquaint the designer with available data and the Department's procedures for acquiring it.

6.2.2 Sources

Much of the data and information necessary for the design of highway drainage facilities may be obtained from some combination of the sources listed in Appendix 6.A. The following information is given for each data source on the list:

- type of data,
- address of source, and
- comments on data.

6.2.3 Geographic Information Systems (GIS)

The Department's geographic information system (GIS) may be used as a source of georeferenced hydrologic data required in hydraulic design decision making. For example, a GIS can be used to develop and store a database containing the land cover, soil type and topography for an agency's entire area of jurisdiction. This database may then be used to produce the existing and ultimate development hydrographs and an array of maps, graphs and tables needed to complete the hydrologic analysis.

The current state-of-the-art understanding of GIS data gathering in hydrologic models is available from numerous textbooks including, *Geographic Information Systems: An Introduction* (Star and Estes, 1990), *Geographic Information Systems: A Management Perspective* (Aronoff, 1990), *Geographic Information Systems — A Guide to the Technology* (Antenucci, et. al., 1992) and HDS No. 6 *(2)*.

6.2.4 National Flood Insurance Program

Many streams have been analyzed for local flood insurance studies. In these cases, data collection is normally unnecessary because the discharges and hydraulic models are normally available from FEMA. Even though these studies are a good source of data, their technical content should be reviewed prior to using the data. Many of the studies are outdated and/or will not reflect changes that may have occurred in the study reach since its initial publication.

6.3 TYPES OF DATA NEEDED

6.3.1 General

The designer must compile the data that are specific to the subject site. Following are the major types of data that may be required:

- permit requirements;
- watershed characteristics;
- stream-reach data (especially in the vicinity of the facility);
- other physical data in the general vicinity of the facility (e.g., utilities, easements);
- hydrologic and meteorologic data (stream-flow and rainfall data related to maximum or historical peak and low-flow discharges and hydrographs applicable to the site);

- existing and proposed land-use data in the subject drainage area and in the general vicinity of the facility;
- anticipated changes in land-use and/or watershed characteristics; and
- floodplain, environmental regulations and archaeological data.

Watershed, stream-reach and site characteristic data, and data on other physical characteristics can be obtained from a field reconnaissance of the site. Examination of available maps and aerial photographs of the watershed is also an excellent means of defining physical characteristics of the watershed.

6.3.2 Drainage Surveys

The designer should inspect the site and its contributing watershed to determine the required field and/or aerial drainage survey to be undertaken as part of the hydraulic analysis and design. Survey requirements for small drainage facilities (e.g., small culverts) are less extensive than those for major facilities (e.g., bridges). However, the purpose of each survey is to provide an accurate picture of the conditions within the zone of hydraulic influence of the facility. Appendix 6.B contains Agency instructions for minor and major drainage surveys.

Following are the data that can be obtained or verified:

- contributing drainage area characteristics;
- stream-reach data (e.g., cross sections, thalweg profile);
- existing structures;
- location and survey for development, existing structures, etc., that may affect the determination of allowable flood levels, capacity of proposed drainage facilities or acceptable outlet velocities;
- drift/debris characteristics;
- general ecological information on the drainage area and adjacent lands; and
- high-water elevations including the date of occurrence.

Much of these data must be obtained from an on-site inspection. It is often much easier to interpret published sources of data after an on-site inspection. Only after a thorough study of the area and a complete collection of all required information should the designer proceed with the final design of the hydraulic facility. All pertinent data and facts gathered through the survey shall be documented as explained in Chapter 4, Documentation. Appendix 6.B contains examples of how the Agency commonly documents the field or aerial survey data discussed in this Chapter.

6.3.3 Watershed Characteristics

Following is a brief description of the major data topics that relate to drainage facility analysis and design. Additional discussion is contained in Chapter 2 of Reference *(1)*.

6.3.3.1 Watershed Characteristics

CONTRIBUTING SIZE. The size of the contributing drainage area expressed in acres or square miles is determined from some or all of the following:

- direct field surveys with conventional surveying instruments;
- use of USGS topographic maps, aerial photographs, digital elevation models, together with field checks to determine any changes in the contributing drainage area such as:
    - terraces;
    - lakes, sinks;
    - debris or mud flow barriers;
    - reclamation/flood-control structures;
    - irrigation diversions; and
    - storm drainage systems;
- use of State Highway Planning Survey Maps; and
- use of aerial maps or aerial photographs.

Other topographic maps of the drainage area may also be obtained from municipal and county entities and local developers.

In determining the size of the contributing drainage area, any subterranean flow or any areas outside the physical boundaries of the drainage area that have runoff diverted into the drainage area being analyzed shall be included in the total contributing drainage area. In addition, it must be determined if flood-waters are diverted out of the basin before reaching the site.

SLOPES. The slope of the stream and the average slope of the watershed (basin slope) should be determined. Hydrologic and hydraulic procedures in other chapters of this *Manual* are dependent on watershed slopes and other factors.

6.3.3.2 Watershed Land Use

The following applies:

- Define and document the present and expected future land use, particularly the location, degree of anticipated urbanization and data source.
- Information on existing use and future urbanization trends may be obtained from:
    - field review,
    - aerial photographs (conventional and infrared),
    - zoning maps and master plans,
    - USGS and other maps,
    - municipal planning agencies, and
    - landsat (satellite) images.
- Specific information about particular tracts of land can often be obtained from owners, developers, realtors and local residents. Care should be exercised in using data from these

sources because their reliability may be questionable, and these sources may not be aware of future development within the watershed that might affect specific land uses.

- Existing land-use data for small watersheds can best be determined or verified from a field survey. Field surveys shall also be used to update information on maps and aerial photographs, especially in basins that have experienced changes in development since the maps or photos were prepared. Infrared aerial photographs may be particularly useful in identifying types of urbanization at a point in time.

6.3.3.3 Streams, Rivers, Ponds, Lakes, Wetlands and Detention Basins

At all streams, rivers, ponds, lakes and wetlands that will affect or may be affected by the proposed structure or construction, the following data shall be secured. These data are essential in determining the expected hydrology and may be needed for regulatory permits:

- Outline the boundary (perimeter) of the water body for the ordinary highwater.
- Determine elevation of normal and highwater for various frequencies.
- Prepare detailed description of any natural or manmade spillway or outlet works including dimensions, elevations and operational characteristics.
- Determine classification of waters in the State.
- Prepare detailed descriptions of any emergency spillway works including dimensions and elevations.
- Document descriptions of adjustable gates, soil and water-control devices.
- Prepare profile along the top of any dam and a typical cross section of the dam.
- Determine the use of the water resource (stock water, fish, recreation, power, irrigation, municipal or industrial water supply).
- Note the existing conditions of the stream, river, pond, lake or wetlands as to turbidity and silt.
- Determine riparian ownership(s) (and any water rights).

6.3.3.4 Environmental Considerations

The need for environmental data in the engineering analysis and design stems from the need to investigate and mitigate possible impacts due to specific design configurations. Environmental data needs may be summarized as follows:

- Identify information necessary to define the environmental sensitivity of the facility's site relative to impacted surface waters (e.g., water use, water quality and standards, aquatic and riparian wildlife biology and wetlands information). Some of this information is available in the water-quality standards and criteria published by the Utah Division of Water Rights.

- Physical, chemical and biological data for many streams are also available from State and Federal water pollution control agencies, USGS and municipalities, water districts and industries that use surface waters as a source of water supply. In unique instances, a data collection program possibly lasting several years and tailored to the site may be required.

- Gather information necessary to determine the most environmentally compatible design (e.g., circulation patterns, sediment transport data). Data on circulation, tides, water velocity, water quality and wetlands are available from the USGS, USACE, universities, marine institutes and State, Federal and local agencies and organizations. Information on sediment transport is vital in defining the suitability of a stream for most beneficial uses including fish habitat, recreation and water supply. It may be essential for projects in critical water-use areas such as near municipal or industrial water supply intakes.

- Information necessary to define the need for and design of mitigation measures shall be obtained (e.g., fish characteristics (type, size, migratory habits), fish habitat (depth, cover, pool-riffle relationship), sediment analysis and water-use and quality standards). Fish and fish habitat information is available from State and Federal fish and game agencies.

- Wetlands are unique and data needs can be identified through coordination with State game and fish agencies and USFWS, etc.

6.3.4 Site Characteristics

A complete understanding of the physical nature of the natural channel or stream reach is of prime importance to a good hydraulic design — particularly at the site of interest. Any work being performed, proposed or completed that changes the hydraulic efficiency of a stream reach must be studied to determine its effect on the stream flow. The designer should be aware of plans for channel modifications and any other changes that might affect the facility design. The stream may be classified as:

- rural or urban;
- improved or unimproved;
- narrow or wide;
- rapid or sluggish flow;
- stable, transitional or unstable;
- sinuous, straight, braided, alluvial or incised; and
- perennial or intermittent flow.

Geomorphological data are important in the analysis of channel stability and scour. Types of needed data are:

- sediment transport and related data,
- stability of form over time (braided and meandering),
- scour history/evidence of scour, and
- bed and bank material identification.

6.3.4.1 Roughness Coefficients

Roughness coefficients, ordinarily in the form of Manning's n values, shall be estimated for the entire flood limits of the stream. A tabulation of Manning's n values with descriptions of their applications can be found in Chapter 8, Channels.

6.3.4.2 Stream Profile

Stream-bed profile data shall be obtained, and these data should extend sufficiently upstream and downstream to determine the average slope and to encompass any proposed construction or aberrations. Identification of "headcuts" that could migrate to the site under consideration are particularly important. Profile data on live streams shall be obtained from the water surface, where there is a stream gage relatively close, the discharge, date and hour of the reading shall be obtained.

6.3.4.3 Stream Cross Sections

Stream cross section data shall be obtained that represent the conditions at the structure site. Stream cross section data should also be obtained at other locations where stage-discharge and related calculations will be necessary.

6.3.4.4 Existing Structures

The location, size, description, condition, observed flood stages and channel section relative to existing structures on the stream reach and near the site shall be secured to determine their capacity and effect on the stream flow. Any structures, downstream or upstream, that may cause backwater or retard stream flow shall be investigated. Also, the manner in which existing structures have been functioning with regard to such items as scour, overtopping, debris and ice passage, fish passage, etc., shall be noted. With bridges, these data shall include span lengths, type of piers and substructure orientation, which usually can be obtained from existing structure plans. The necessary culvert data includes size, inlet and outlet geometry, slope, end treatment, culvert material and flow-line profile. "As-built" highway construction plans may be available to obtain required bridge and/or culvert data. Photographs and high-water profiles or marks of flood events at the structure and past flood scour data can be valuable in assessing the hydraulic performance of the existing facility.

6.3.4.5 Acceptable Flood Levels

Development and property use adjacent to the proposed site, both upstream and downstream, may determine acceptable flood levels. Floor elevations of structures or fixtures shall be noted. In the absence of upstream development, acceptable flood levels may be based on tailwater and freeboard requirements of the highway itself. In these instances, the presence of downstream development may determine appropriate overflow points when an overtopping design of the highway is considered.

6.3.4.6 Flood History

The history of past floods and their effect on existing structures are of exceptional value in making flood hazard evaluation studies, and they provide needed information for sizing structures. Information may be obtained from newspaper accounts, local residents, flood marks or other positive evidence of the height of historical floods. Changes in channel and watershed conditions since the occurrence of the flood shall be evaluated in relating historical floods to present conditions.

Recorded flood data are available from agencies such as:

- USACE,
- USGS,
- NRCS,
- FEMA,
- US Bureau of Reclamation, and
- Utah Division of Water Rights.

6.3.4.7 Debris and Ice

The quantity and size of debris and ice carried or available for transport by a stream during flood events shall be investigated and such data obtained for use in the design of structures. In addition, the times of occurrence of debris and ice in relation to the occurrence of flood peaks should be determined, and the effect of backwater from debris and ice jams on recorded flood heights should be considered when using stream flow records. Data related to debris and ice considerations can be obtained from (list sources for such data).

6.3.4.8 Scour Potential

Scour potential is an important consideration relative to the stability of the structure over time. Scour potential will be determined by a combination of the stability of the natural materials at the facility site, tractive shear force exerted by the stream and sediment transport characteristics of the stream. Data on natural materials can be obtained from Utah Department of Agricolture or by tests at the site.

Bed and bank material samples sufficient for classifying channel type, stability and gradations, and a geotechnical study to determine the substrata if scour studies are needed, will be required. The various alluvial river computer model data needs will help clarify what data are needed. Also, these data are needed to determine the presence of bed forms so that a reliable Manning’s roughness coefficient and bed-form scour can be estimated.

6.3.4.9 Controls Affecting Design Criteria

Many controls will affect the criteria applied to the final design of drainage structures including allowable headwater level, allowable flood level, allowable velocities and resulting scour and other site-specific considerations. Data and information related to such controls can be obtained from Federal, State and local regulatory agencies, and site investigations to determine what natural or man-made controls shall be considered in the design. In addition, there may be downstream and upstream controls that shall be documented.

6.3.4.10 Downstream Control

Any ponds or reservoirs, including their spillway elevations and design levels of operation, shall be noted because their effect on backwater and/or streambed aggradation may directly influence the proposed structure. Also, any downstream confluence of two or more streams shall be studied to determine the effects of backwater or streambed change resulting from that confluence.

6.3.4.11 Upstream Control

Upstream control of runoff in the watershed shall be noted. Conservation and/or flood control reservoirs in the watershed may effectively reduce peak discharges at the site and may also retain some of the watershed runoff. Capacities and operational designs for these features shall be obtained. NRCS, USACE, Bureau of Reclamation, consulting engineers and other reservoir sponsors often have complete reports concerning the operational and design of proposed or existing conservation and/or flood control reservoirs.

The redirection of flood waters can significantly affect the hydraulic performance of a site. Some actions that redirect flows are irrigation facilities, debris jams, mud flows and highways or railroads.

6.4 SURVEY INFORMATION

6.4.1 General

Complete and accurate survey information is necessary to develop a design that will best serve the requirements of a site. The Department Regions’ location crews in charge of the drainage survey shall have a general knowledge of drainage design and, as such, shall coordinate the data collection with the designer. The amount of survey data gathered shall be commensurate with the importance and cost of the proposed structure and the expected flood hazard as discussed in Section 6.3.2 and Appendix 6.B.

At many sites, photogrammetry is an excellent method of securing the topographical components of drainage surveys. Planimetric and topographic data covering a wide area are easily and cost effectively obtained in many geographic areas. A supplemental field survey is required to provide data in areas obscured on the aerial photos (e.g., underwater and heavy vegetation).

Data collection shall be as complete as possible during the initial survey to avoid repeat visits. Thus, data needs must be identified and tailored to satisfy the requirements of the specific location and size of the project early in the project design phase. Coordination by the Regions’ location crews with all sections requiring drainage-related survey data before the initial field work is begun will help ensure the acquisition of sufficient, but not excessive, survey data.

6.4.2 Requirements

The Department instructions for hydraulic surveys are contained in the UDOT Drainage Manual. An outline of these requirements is presented in Appendix 6.B. An Example Field Investigation Form and Hydraulic Survey Field Inspection Check List are provided in Appendix 6.C.

6.5 DATA COLLECTION

6.5.1 Digital and Satellite Data Models

Several methods to use electronic data for hydraulic and hydrologic studies are available. Design of drainage systems can be accomplished using CADD software and electronic surface data. Hydrologic and hydraulic models can be developed using this data.

The types of data normally used by digital models are:

- elevation data;
- features (e.g., streams and roadways);
- land use; and
- soils and infiltration.

Some of the electronic data is readily available, though not always with the desired resolution. Elevation data is available from the USGS in DEM format. The data is normally available in UTM coordinates and in 15 ft to 300 ft resolution, depending on the location. NRCS also maintains soil and land-use data basis in GIS formats in certain areas. Detailed hydraulic and hydrologic studies may require higher resolution elevation data than is normally available through USGS and NRCS. Higher resolution data is sometimes available through local municipalities.

Satellite imagery is available through commercial vendors. However, elevation data is not normally available through these sources, and the technology to extract it is not yet available. Satellite imagery can be used to determine land uses. Due to the scarcity or obsolescence of elevation data, the normal approach is to develop topographic surveys for a project. There are two basic methods to develop topographic surveys:

- aerial photogrammetry, and
- field data collection.

6.5.2 Aerial Photogrammetry

Under this method, topographic mapping is developed using pictures of the ground taken from an aircraft or satellite. Ground controls are established using field survey methods and contours are developed.

Aircraft used for taking photographs can be fixed wing (airplane) or helicopter. Fixed wing still is the most economical method; however, helicopter based surveys offer low altitude flights, resulting in much higher accuracy. The pictures taken can also be used as data for hydraulic investigations and studies.

High-resolution satellite and multi-spectral imagery is available and may be substituted for other methods if necessary. Because satellite data is stored for a period of time, multi-spectral satellite imagery can also be used to investigate flooding, actually after an event has occurred. Potentially, the technology can be used to develop “before-and-after” images and topography to investigate a flood event or other significant change in an area of interest.

A new method of aerial topographic generation is using laser or radar beams from an aircraft carrying differential GPS. The laser based method is called Light Detection and Ranging (LIDAR). LIDAR or radar generated data have the advantage of being inexpensive when compared to traditional photogrammetry. However, the accuracy is highly dependent on the technology available to the vendor in aerial equipment and available software to filter trees and other covered land areas.

6.5.3 Field Data Collection

Field data collection is normally accomplished using electronic survey equipment such as Total Station and Global Positioning System (GPS).

Using Total Station as a data collection tool, the engineer can develop topographic mapping directly from the fieldwork, with little additional processing. This information can be directly used in certain highway or hydraulics software, saving time and resources in the tedious process of survey decoding and data entry. Digital Elevation Models (DEMs) or Digital Surface Models can be developed using the data collected using this method. Other feature data (e.g., flood limits, bank full indicators, vegetation markers, point bars, flow boundaries) can also be located by a surveyor and automatically decoded along with the elevation data. The accuracy of this method can be very high and is dependent on the experience of the field personnel.

GPS based surveying is still less accurate because it depends on many factors such as location of the survey reach and time of day. Hand-held GPS units that have sub-meter horizontal precision are available. Vertical precision to collect elevation data is not sufficiently accurate for many design functions. However, this method makes a one-person survey crew possible with minimal training. GPS data can be obtained by a hydraulics engineer during a field visit. This facilitates rapid development of field data, especially location data, and quick office evaluations.

6.5.4 Data Merging

Merging of electronic surface data is common during highway design. Better data is usually collected within the highway area, while the data for the area outside the expected cut/fill lines is less precise. Because watershed limits fall well outside the highway cut/fill lines, hydraulics engineers must negotiate with the data that has multiple resolutions.

Electronic data is available in various forms differentiated by software products, type of data structure (DEMs and TINs), coordinate systems (UTM, State Plane, Latitude-Longitude), units (feet or meters), resolution and datums. While merging data in different forms, care must be taken to ensure proper conversion prior to merging. Standardizing all data to the most current format is the best way to ensure compatibility. There are tools available to accomplish the data "translation."

A more serious issue in data merging is caused by differences in data resolution. For example, a digital surface model developed using a photogrammetric method is typically of a lower resolution compared to a surface model developed using a field data collection survey. When merging the data, elevation differences at the boundaries of the different data areas must be carefully reconciled.

There is often a problem with artificial pits (sinks) and peaks due to the creation of DEMs and TINs. The engineer must evaluate the data and correct these inconsistencies.

6.5.5 Accuracy of Data

In any engineering computations, it is important to understand the limitations of accuracy of the computations based on the accuracy of the input data. In step-backwater computations utilizing HEC-RAS or WSPRO, there are several factors that have significant effects on the accuracy of the results: accuracy of the survey data, spacing between cross sections, correct establishment of upstream and downstream study limits, selection of roughness coefficients.

Most field surveys of channel and floodplain cross sections are recorded to an accuracy of 0.1 ft. If the survey truly represents the cross sections of the reach of the stream being studied to a 0.1 ft accuracy, the greatest accuracy that would result from a step-backwater computation could be no more than 0.1 ft. Any results expressed more precisely than 0.1 ft are simply due to the mathematics.

The accuracy of aerial survey technology for generating cross sectional coordinate data is governed by mapping industry standards. Cross sections obtained from contours of topographic maps developed by photogrammetric methods are generally not as accurate as those generated from field data collection methods. Aerial photography can supplement field survey cross sections. The use of aerial elevation survey technology permits additional coordinate points and cross sections to be obtained at small incremental cost, and the coordinate points may be formatted for direct input into commonly used water surface profile computer programs such as HEC-RAS and WSPRO.

For further information on determining the relationships between (1) survey technology and accuracy employed for determining stream cross sectional geometry, (2) degree of confidence in selecting Manning's roughness coefficients, and (3) the resulting accuracy of hydraulic computations, refer to the USACE publication Technical Paper No. 114 (Reference *(4)*). This publication also presents methods of determining the upstream and downstream limits of data collection for a hydraulic study requiring a specified degree of accuracy. Computer software has been developed to perform the calculations for the various routines presented in these publications. "Preliminary Analysis System" (PAS) (Reference *(3)*) is available from the McTrans Center, University of Florida, Gainesville, FL.

6.6 FIELD REVIEWS

6.6.1 <u>On-Site Inspection</u>

Field reviews shall be made by location crew for the designer to become familiar with the site. The most complete survey data cannot adequately depict all site conditions or substitute for personal inspection by someone experienced in drainage design. Factors that most often need to be confirmed by field inspection are:

- selection of roughness coefficients,
- evaluation of apparent flow direction and diversions,
- flow concentration,
- observation of land use and related flood hazards,
- geomorphic relationships,
- high-water marks or profiles and related frequencies,
- existing structure size and type, and
- existence of wetlands.

An actual visit to the site where the project will be constructed shall be made before final hydraulic design is undertaken. This may be combined with the visit by others (e.g., the roadway and structural designers, environmental reviewers, local officials). The designer may visit the site separately, however, because of interests that are different from the others and the time required to obtain the data as warranted below.

There are several criteria that shall be established before making the field visit. Can any needed information be obtained from maps, from aerial photos or by telephone calls? What kind of equipment should be taken and, most important, what exactly are the critical items at this site? Photographs shall be taken. At a minimum, photos shall be taken looking upstream and downstream from the site and along the contemplated highway centerline in both directions. Details of the stream bed and banks should also be photographed plus structures in the vicinity both upstream and downstream. Close-up photographs complete with a scale or grid shall be taken to facilitate estimates of the stream-bed gradation.

6.6.2 Check List

The forms to be used by the Department in identifying and cataloging field information are shown in Appendix 6.C.

6.7 DATA EVALUATION

6.7.1 Objective

Once the needed data have been collected, the next step is to compile it into a usable format. The designer must ascertain whether the data contains inconsistencies or other unexplained anomalies that might lead to erroneous calculations or results. The main reason for analyzing the data is to draw all of the various pieces of collected information together and to fit them into a comprehensive and accurate representation of the hydrologic and hydraulic characteristics of a particular site.

6.7.2 Evaluation

Data should always be subjected to careful study by the engineer for accuracy and reliability. Experience, knowledge and judgment are important parts of data evaluation. It is in this phase that reliable data shall be separated from that which is less reliable and historical data combined with that obtained from measurements. The data shall be evaluated by the engineer for consistency and to identify any changes from established patterns. Reviews shall be made of such items as previous studies and old plans for types and sources of data, how the data were used and any indications of accuracy and reliability. Historical data shall be reviewed to determine whether significant changes have occurred in the watershed and whether these data can be used. Data acquired from the publications of established sources such as USGS can usually be considered as valid and accurate. Data should always be subjected to careful study by the designer for accuracy and reliability.

Basic data (e.g., streamflow data derived from non-published sources) shall be evaluated and summarized before use. Maps, aerial photographs, Landsat images and land-use studies shall be compared with one another and with the results of the field survey and any inconsistencies resolved. General references shall be consulted to help define the hydrologic character of the site or region under study and to aid in the analysis and evaluation of data.

6.7.3 Sensitivity

Sensitivity studies may be used to evaluate data and establish the relative importance of specific data items to the final design. Sensitivity studies consist of conducting a design with a range of values for specific data items. The effect on the final design can then be established.

This is useful in determining what specific data items have major effects on the final design and the importance of possible data errors. Time and effort shall then be spent on the more sensitive data items making sure these data are as accurate as possible. This does not mean that inaccurate data are accepted for less sensitive data items, but it allows prioritization of the data collection process given a limited budget and time allocation.

The results of this type of data evaluation shall be used so that as reliable a description as possible of the site can be made within the allotted time and the resources committed to this effort. The effort of data collection and evaluation shall be commensurate with the importance and extent of the project and/or facility.

6.8 REFERENCES

(1) AASHTO, *Highway Drainage Guidelines*, Chapter 2 “Hydrology,” Task Force on Hydrology and Hydraulics, 2003.

(2) Federal Highway Administration, *Highway Hydrology*, Hydraulic Design Series No. 2, FHWA-SA-96-067, 1996.

(3) Federal Highway Administration, *Preliminary Analysis System for WSP*, HY-11, 1989.

(4) US Army Corps of Engineers, “Accuracy of Computer Water Surface Profiles,” Technical Paper No. 114, Hydrologic Engineering Center, 1986.

APPENDIX 6.A — SOURCES OF DATA

Principal Hydrologic Data Sources

- METEOROLOGICAL DATA
  National Oceanic and Atmospheric Agency (NOAA)
  National Climatic Data Center
  37 Battery Park Avenue
  Federal Building
  Asheville, North Carolina 28801
  (704) 271-4800 FAX (704) 271-4876

- REGIONAL AND LOCAL FLOOD STUDIES
  USGS regional and any site studies
  Surveyed high-water marks and site visits by Utah Division of Water Rights

- HYDROLOGY DATA FROM OTHERS (see below)

Principal Watershed Data Sources

- USGS maps (“Quad” sheets)
  US Geological Survey
  Rocky Mountain Mapping Center
  Mail Stop 504
  Denver Federal Center
  Denver, Colorado 80225
  (303) 236-5829

- EROS AERIAL PHOTOGRAPHS
  US Geological Survey
  EROS Data Center
  Sioux Falls, South Dakota 57198
  (605) 594-6151

- NRCS and BLM Soils Maps
- Site visits by UDOT
- Watershed data from others (see below)

Principal Regulatory Data Sources

- FEDERAL FLOODPLAIN DELINEATIONS AND STUDIES
  Federal Emergency Management Agency
  Flood Map Distribution Center
  6930 (A-F) San Tomas Road
  Baltimore, Maryland 21227-6227
  (800) 358-9616

- FHWA DESIGN CRITERIA AND PRACTICES

Federal Highway Administration
US Department of Transportation
400 Seventh Street SW
Washington, D.C. 20590

- *FEDERAL REGISTERS*
  Superintendent of Documents
  US Printing Office
  Washington, D.C. 20402
  (202) 783-3238

- USACE SECTION 404 PERMIT PROGRAM (see Environmental below)

- USCG

- USEPA (see Environmental below)

- Utah EPAs (see Environmental below)

- UTAH FLOODPLAIN DELINEATIONS AND STUDIES - FEMA

- UTAH CODE

- LOCAL ORDINANCES AND MASTER PLANS

Principal Environmental Data Sources

- USEPA data and studies

- USACE data and studies

- USGS water quality data

- Utah water quality data

- Environmental statements prepared by other Federal, State and local agencies and private parties

- Environmental data from others (see below)

Principal Demographic, Economic and Political Data Sources

- State of Utah, Department of Demographic and Economic Analysis

Other Data Sources

- US Bureau of Reclamation (USBR)
  US Bureau of Reclamation Center
  Denver, Colorado 80225
  (303) 236-8098

- Regional and State US Bureau of Land Management (USBLM)
- Regional US Environmental Protection Agency (USEPA)
- Regional US Federal Emergency Management Agency (FEMA)
- Regional and State US Fish and Wildlife Service (USFWS)
- Regional and State US Forest Service (USFS)
- Regional and State US Natural Resources Conservation Service (NRCS)
- Regional and State US Army Corps of Engineers (USACE)
- Regional and State US Geological Survey (USGS)
- Regional and State Federal Highway Administration (FHWA)
- National Weather Service (NWS)
    - National Oceanic and Atmospheric Administration (NOAA)
- Utah Division of Water Rights
- Utah Department Environmental Quality
- Local Flood Control Districts
- Any Indian councils
- Municipal governments
- Private citizens
- Private industry

APPENDIX 6.B — HYDRAULIC SURVEY INSTRUCTIONS

Major hydraulic survey - rivers and streams
Extend survey at least one bridge length (min. 150 ft) upstream and downstream of the bridge. The width of the survey should be inclusive of the natural floodplain and extend at least 100-feet from the top of natural banks on each side of the river/stream.

The survey should include the following:

- All grade brakes within the floodplain,
- All major features within the floodplain, including trees, structure, erected formations, buildings, bushes and any other possible obstruction to the flow,
- Location of the bridge abutments, wing wall or any bridge features within the natural river/stream channel.
- Bridge features including low cord, top of pavement and pavement geometry. Identify type of parapet, type of abutments, beams and any other features that may encroach the waterway.

APPENDIX 6.C — FIELD INVESTIGATION FORMS

Form 1
FIELD INVESTIGATION FORM

DATE ____________________
PROJECT ____________________
BY____________________

STRUCTURE TYPE____________________

SIZE OR SPAN ____________________
OF BARRELS OR SPANS ____________

CLEAR HT ____________________

ABUT TYPES ____________________

INLET TYPE ____________________
EXISTING WTWY COVER ____________
OVERFLOW BEGINS @ E.L. ____________

MAX AHW ____________________
REASON: ____________________
____
____

PIERS: TYPE ____________________

SKEW ____________________

INLET ____________________
OULET ____________________

% GRADE OF ROAD ____________________

% GRADE OF STREAM ____________________

LENGTH OF OVERFLOW ____________
CHECK FOR DEBRIS ____________
CHECK FOR ICE ____________
SIDE SLOPES ____________
HEIGHT OF BANKS ____________

UP OR DOWNSTREAM RESTRICTION: ____________________

OUTLET CHANNEL, BASE: ____________________

MANNING’S n VALUE: ____________________

TYPE OF MATERIAL IN STREAM ____________________
PONDING ____________________

CHECK BRIDGES UPSTREAM AND DOWNSTREAM

CHECK LAND USE UPSTREAM AND DOWNSTREAM

SURVEY REQUIRED? Yes ___ No ___

REMARKS: ____________________
____
____
____

Form 2
HYDRAULIC SURVEY FIELD INSPECTION CHECK LIST

I. GENERAL PROJECT DATA

1. Project Number:_________________ 2. County:____
3. Project Name:____
4. Site Name:____________________, Station ______________ M.P.________________________
5. Site Description: ( ) Cross drain, ( ) Irrigation, ( ) Storm Drain, ( ) Long. Encroach, ( ) Ch. Change,
   ( ) Other: ____
6. Survey Source: ( ) Field, ( ) Aerial, ( ) Others:______________________________________
7. Date Survey Received:_________, From:____
8. Site Inspected by______________________________ on ___________ (name)
   (name) (date)

II. OFFICE PREPARATION FOR INSPECTION

1. Reviewed:
   Aerial Photos: ( ) Yes, Photo #s __________, ( ) None Available
   Mapping/Maps: ( ) Yes, Map #s ___________, ( ) None Available
   Reports: ( ) Yes, ( ) No, ( ) None Available at this time
   ((Agency)) Permanent File: ( ) Yes, ( ) No, ( ) No file data found

2. Special Requirements and Problems Identified for Field Checking:

   ( ) Hydrologic Boundary: obtain hydrologic channel geometry
   ( ) Adverse Flood History: obtain HW Marks/dates/eyewitness
   ( ) Irrigation Ditch: obtain several Water Right depths
   ( ) Permits Req'd: ( ) USACE ( ) Ch. Change, ( ) Dam, ( ) USCG, ( ) NFIP, ( ) Dr. District
   ( ) Other:____
   ( ) Adverse Channel Stability and Alignment History: Check for headcutting, bank caving, braiding increased meander activity
   ( ) Structure Scour: check flow alignment, scour at culvert outlet or evidence of bridge scour
   ( ) Obtain bed/bank material samples at ____

III. FIELD INSPECTION

(The following details obtained at the site are annotated on the Drainage Survey)

1. Survey appears correct: ( ) Yes, ( ) Apparent errors are: ______________________________
   ____ that were resolved by:
   ____

2. Flooding Apparent? ( ) No, ( ) Yes, HW marks obtained, ( ) Yes, but HW marks not obtained because
   ____

3. Do all Floods Reach Site? ( ) Yes, ( ) No, details obtained, ( ) No, but details not obtained because __
   ____

4. Do Floodwaters Enter Irrigation Ditch? ( ) N/A, ( ) No, ( ) Yes, details obtained, ( ) Yes, but details not obtained because ____
   ____

5. Hydrologic Ch. Geometry obtained? ( ) Yes, ( ) No because____________________________
   ____

6. Channel Unstable? ( ) No, ( ) Yes because of ( ) headcutting observed and ( ) amount/location obtained, ( ) bank caving, ( ) braiding, ( ) increased meander activity, ( ) Other____________________
____

7. Structure Scour in Evidence? ( ) No, ( ) Minor, ( ) Yes and ( ) obtained bed/bank samples and ( ) noted any flow alignment problems, ( )Yes and ( ) bed/bank material samples not obtained and ( ) flow alignment not noted because ____
____

8. Irrigation facility? ( ) No, ( ) Yes, several water right related depths obtained, ( ) Yes, no water right related depths obtained because ____
____

9. Manning's n obtained? ( ) Yes, ( ) No because ____
____

10. Property damage due to BW? ( ) No ( ) Yes, elevation/property type checked, ( ) Yes, but elevation/property type not obtained because ____
____

11. Environmental Hazards Present? ( ) No, ( ) Yes, details obtained, ( ) Yes, details not obtained because ____
____

12. Ground Photos Taken? ( ) Upstream floodplain and all property, ( ) Downstream floodplain and all property, ( ) Site looking from downstream, ( ) Site looking from upstream, ( ) Channel material w/scale, ( ) Evidence of channel instability, ( ) Evidence of scour, ( ) Existing structure inlet/outlet, ( ) Other ____
____

13. Effective drainage area visually verified? ( ) Yes, ( ) No because_______________________________
____

IV. <u>POST INSPECTION SURVEY ANNOTATION</u>

1. Section II Findings annotated on survey? ( ) Yes, ( ) No, see section attached (attach typed explanation by site station and site name, and check list section and number).

2. Survey Originals and check lists forwarded to ( ) ((Agency's Roadway Unit, ___________ ea. site's)), and the ( ) ((Agency's Hydraulics Unit, ___________ ea. site's)) for hydraulic design.

/s/

((Designer Making Inspection))